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TESTING AND MONITORING PLAN
40 CFR 146.90

PROJECT MINERVA

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1.0 Introduction

This Testing and Monitoring Plan describes how Gulf Coast Sequestration (GCS) will monitor the Project Minerva site pursuant to 40 CFR 146.90. In addition to demonstrating that the well is operating as planned, the carbon dioxide plume and pressure front are moving as predicted, and that there is no endangerment to USDWs, the monitoring data will be used to validate and adjust the geological models used to predict the distribution of the CO_2 within the storage zone to support AoR reevaluations and a non-endangerment demonstration.

Results of the testing and monitoring activities described below may trigger action according to the Emergency and Remedial Response Plan.

1.1 Facility Information

Facility name:	Project Minerva Wells 1-4
Facility contact:	Benjamin Heard, Principal 2417 Shell Beach Drive, Lake Charles, Louisiana 70601 (713) 320.2497; bheard@gcscarbon.com
Well location:	Calcasieu/Cameron Parish, Louisiana Well No 1: [redacted] Well No 2: [redacted] Well No 3: [redacted] Well No 4: [redacted]

2.0 Overall Strategy and Approach for Testing and Monitoring

The Testing and Monitoring Plan is adapted to site area and considers the following site: specific parameters:

1. The injection zone (Frio Formation) ranges from 1,000 to 1,600 ft gross thickness and comprises 23 zones- 12 sandstone zones alternating with 11 shale zones. Each sandstone layer acts as a discrete flow unit, while the shale layers behave as either barriers or baffles.
2. The performance of the Frio Formation in accepting CO_2 injection is well known. The Frio Formation has been used regionally as a target for Underground Injection Control (UIC) Class 1 injection, has hosted and extensively monitored, DOE-funded test injection project in Liberty County, Texas, and has received CO_2 for CO_2 EOR in multiple fields. Two Frio injection sites at Hastings Field and West Ranch Field received anthropogenic CO_2 and have been monitored as part of DOE-funded programs supporting CCUS projects.
3. The performance of the Anahuac Formation as a confining zone is well known because a) it is proven to retain hydrocarbons regionally, and 2) coring and testing programs conducted as part of the UIC Class 1 program have documented the quality of this thick, low permeability mudstone. Analysis has shown that faults in this region do not exhibit sufficient throw to create a flow path vertically through the Anahuac Formation.
4. A thick (>7,000 ft) Miocene interval overlies the Anahuac Formation and comprises highly transmissive sandstones, interbedded regional mudstone seals and local mudstone baffles. Regionally the Miocene contains hydrocarbons and is used for Class 1 injection in both Louisiana and Texas. Fluids in the Miocene are saline; therefore, the Miocene can be considered to perform as an additional barrier to vertical fluid migration as well as allowing for pressure dissipation and as a monitoring point.
5. The primary source of groundwater for the region is the Chicot Aquifer, which is contained within in the transmissive and multi-layered Beaumont Formation. Within the project area of review, however, it is sparsely used. Locally, saline waters may be present in the Chicot Aquifer due to natural salinization near salt domes (e.g. [redacted]) or as the result of legacy oil and gas production activities that failed to adequately protect underground sources of drinking water (USDW). In addition, the Chicot Aquifer is locally charged with both biogenic and thermogenic methane. The monitoring program will document the initial condition of salinization of this aquifer system so that any changes during project operation can be recognized. Available groundwater characterization data are currently limited.
6. Natural seismicity in the area is low, as is the risk of induced seismicity, owing to the high transmissivity and lack of brittle rocks within, above, or below the injection zone (Frio Formation). Previous measurements of seismicity in Gulf Coast projects have not detected events resulting from injection. Consequently, seismicity will be monitored for change in frequency; only if a change in frequency occurs will monitoring of local events be undertaken.
7. Surface monitoring at the Minerva site is designed to be responsive to the near surface setting. The area is dominated by complex surface conditions including tree- and grass-dominated high areas, intermittently flooded freshwater wetland, and perennial wetlands.

The area is expected to be dynamic in terms of CO_2 production and uptake from active environments including wetland bottom sediments, intermittently saturated soils, plant, and animal activities, and is used for grazing and other activities which are likely to change over time. Therefore, no systematic array of leakage detection in air or soil is proposed. We propose instead an anomaly response program, to be deployed if an incident or anomaly with possible surface impact occurs. Historic and recent oil and gas exaction operations surrounding the AoR may also have anomalous surface characteristics related to both natural processes and past fluid management practices.

Four injection wells will create two CO_2 plumes and one area of elevated pressure, resulting in a single merged AoR. The axis of a broad syncline structure was chosen as the site of CO_2 injection to minimize contact between the projected CO_2 plumes and AoR with existing well penetrations. Validation of the magnitude and area of pressure increase during injection is, therefore, a monitoring focus, as well as documenting plume stabilization (described in the Post-Injection Site Care and Site Closure Plan 40 CFR 146.93(a) document).

The monitoring network is composed of the following elements, listed from deepest and closest to injection to the furthest away and shallowest (see Figure 2.1).

1. Monitoring at the pipeline handoff to the injection site will determine the key parameters of mass and purity of CO_2 needed for accounting of mass injected and modeling of the subsurface response to injection.
2. Monitoring at injection wells will assure that the wells are performing as intended to deliver the CO_2 to the subsurface storage zones and measure the pressure response at the reservoir intervals (a key model match parameter). Downhole pressure gauges and injection logging in the four injection wells will be used to assess within-plume reservoir response to injection.
3. A 4-D VSP array composed of fiber optic cables installed downhole at injection wells for Distributed Acoustic Sensing and an array of fixed pads for acoustic sources will allow tracking of the area of CO_2 saturation over time along selected azimuths. For CO_2 plume tracking to match to models, good repeatability to measured change over time is more critical than imagining details of the plume. The source array is aligned to 1) document plume growth during injection and 2) plume stabilization during PISC. The spacing and location of the sources will be determined by the VSP design team and located where feasible to install and allow access in the wetland areas (Figure 2.1).
4. In-zone pressure (IZ) monitoring wells will validate the modeled growth of the AoR over time. IZ pressure-monitoring will be outside of the CO_2 plume areas and can be repurposed by recompletion of existing wells and fitting them with downhole pressure gauges. Change in water composition is not expected in this zone; and water will be sampled once (including for dissolved and free gases) for characterization purposes.
5. Above zone monitoring interval (AZMI) wells will be installed in areas of more abundant penetrations where concern about isolation of the injection zone is higher-than-average. IZ and AZMI monitoring points can be co-located or engineered as multi-zone completions,

if feasible. Change in water composition is not expected in this zone; and water will be sampled once (including for dissolved and free gases) for characterization purposes.

6. An airborne conductivity survey will be used to assess the expected complexity of both the groundwater system and near surface and identify areas of high salinity that may be existent. This will be used to guide finalization of ground water well placement and ecosystem survey locations. A repeat survey at project end will be used to detect changes indicative of possible out-of-zone fluid migration. The survey will be designed and conducted by a qualified vendor.

7. Water wells drilled at each injection well pad will be completed as long-term monitoring points to document changes in water chemistry. Seasonal sampling including field parameters and dissolved, and free gasses and water level monitoring will be conducted 4 times per year for 3 years for characterization. After 3 years sampling frequency will be decreased and targeted to chemical species that are indicative of leakage. Far field groundwater wells will be drilled to characterize anomalous salinity in order to deal with the expected complex salinity signal. Seasonal sampling and water level monitoring will be conducted 4 times per year for 3 years for characterization. After 3 years sampling frequency will be decreased and targeted to species that are indicative of leakage.

8. An ecosystem and land-use survey based on image analysis, followed by site visits, will be conducted over the surface projection of the AoR and adjacent areas of potential anomalous signal. This will document pre-injection (baseline) surface conditions and provide the basis for designing ecosystem surveillance areas. Sampling stations will be located in areas that represent the diversity of ecosystems including disturbed areas and wetlands (about 10 sites). Sample analyses will provide characterization of each ecosystem's respective geochemical signatures for future attribution. Repeat sampling of CO_2, O_2, N_2, CH_4, C1-C5 hydrocarbons, $\delta^{13}C$ and ^{14}C of CO_2 and CH_4 and δD of CH_4 will be performed on carbon phases seasonally (4 times per year) over a 2-year period to provide robust characterization. Sampling will not be routinely repeated but is important to have available in case incident or anomaly occurs. Work will be conducted by a qualified vendor. Models will be developed to provide anomaly intensification thresholds and develop a protocol for incident response on an as-needed basis.

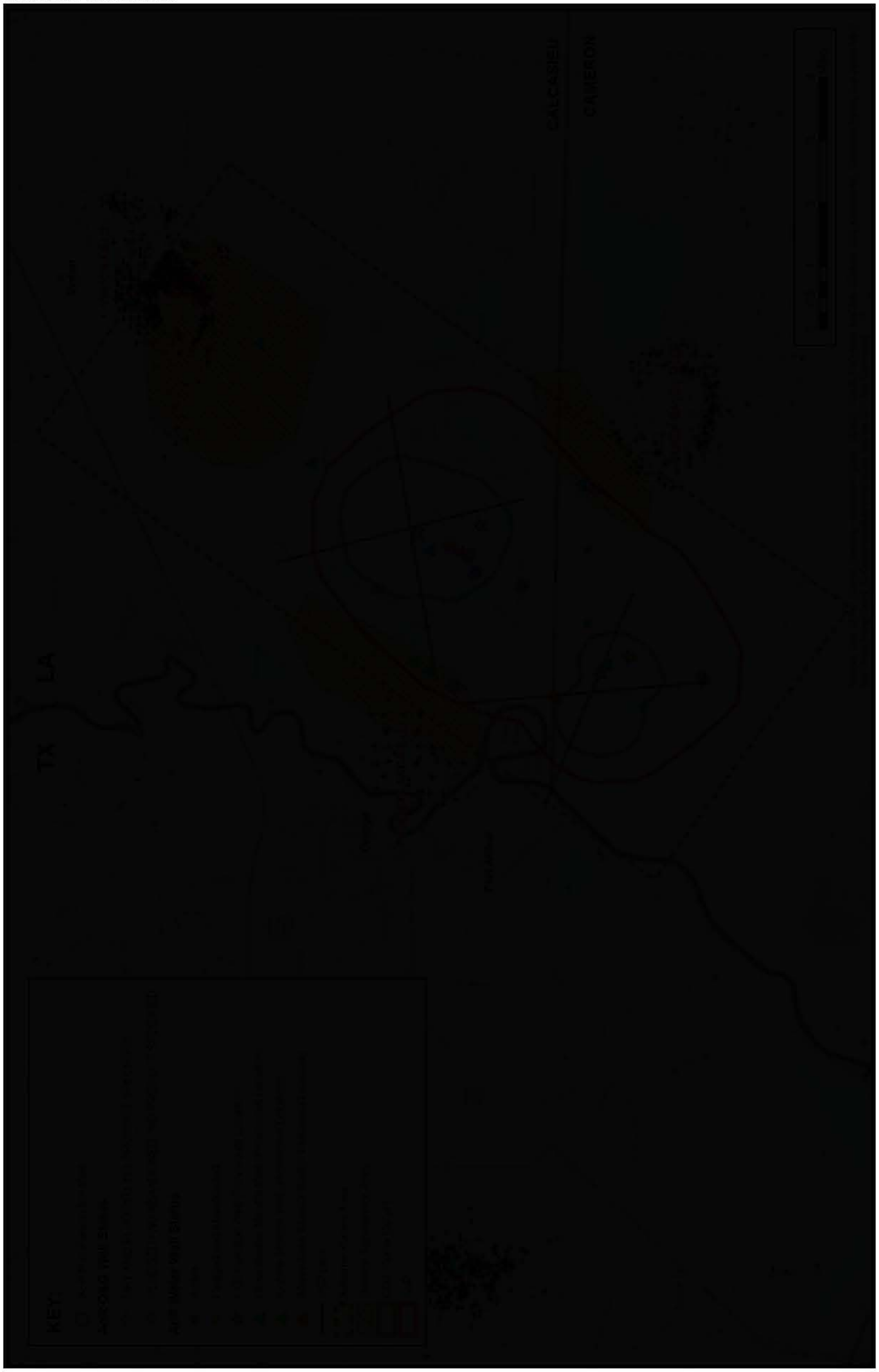

Figure 2.1 Testing and monitoring plan overview

2.1 Quality assurance procedures

A quality assurance and surveillance plan (QASP) for all testing and monitoring activities, required pursuant to 146.90(k), is provided in 12.1 APPENDIX 1: Class VI Injection Well: Quality Assurance and Surveillance Plan.

2.2 Reporting procedures

GCS will report the results of all testing and monitoring activities to the EPA in compliance with the requirements under 40 CFR 146.91.

3.0 Carbon Dioxide Stream Analysis [40 CFR 146.90(a)]

GCS will analyze the CO_2 stream during the operation period to yield data representative of its chemical and physical characteristics and to meet the requirements of 40 CFR 146.90(a).

3.1 Sampling location

CO_2 stream sampling will be conducted for all four injection wells at the storage facility transfer point co-located with a mass flow meter.

3.2 Sampling frequency

Carbon Dioxide Stream sampling will be conducted every 3 months (quarterly) or when known changes to the injected stream occur (i.e., source changes and/or additions/deletions to the existing stream). Density measurements at the mass flow meter greater than normal variability and not correlated to thermal variations also will trigger sampling. The isotopic composition of carbon in CO_2 ($\delta C^{12}/C^{13}$ ratio and C^{14} will be measured once and repeated only if new sources are added.

3.3 Analytical parameters

GCS will contract a vendor to analyze the CO_2 for the constituents identified in Table 3.1 using the methods listed. If the constituents are not found in initial analysis or are screened out at the source prior to CO_2 pipeline transport, this will be documented and, with the prior approval of the UIC Program Director, they will be removed from the list of analytical parameters.

Table 3.1. Summary of analytical parameters for CO_2 stream.

Parameter	Analytical Methods [1]
Carbon Dioxide (CO_2)	ISBT[2] 2.0 Caustic absorption Zahm-Nagel ALI method SAM 4.1 subtraction method (GC/DID) GC/TCD
Water (H_2O)	
Oxygen (O_2)	ISBT 4.0(GC/DID) GC/TCD
Nitrogen (N_2)	ISBT 4.0(GC/DID) GC/TCD
Hydrogen Sulfide (H_2S)	ISBT 14.0 (GC/SCD)
Argon (Ar)	
Sulfur dioxide (SO_2)	ISBT 10.1 GC/FID)
Methane (CH_4)	ISBT 10.1 GC/FID)
Total hydrocarbons (C2H6, C3H8+)	ISBT 10.0 THA (FID)
Hydrogen (H_2)	
Carbon Monoxide (CO)	ISBT 5.0 Colorimetric ISBT 4.0(GC/DID
COS	
Nitrogen Oxides (any (NO_x)	ISBT 7.0 Colorimetric
Glycol	
Compressor oil	
Carbon isotopic composition δC^{13} and C^{14}	Measured once and when a significant new source is added. Used for attribution during monitoring

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director
Note 2. International Society of Beverage Technologists (ISBT) Carbon Dioxide Guidelines MBAA TQ vol. 39, no. 1, 2002, pp. 32-35 as cited in ISO/TR 27921:2020(en). Carbon dioxide capture, transportation, and geological storage — Cross Cutting Issues — CO_2 stream composition

3.4 Sampling methods

The sampling system will step down pressure from pipeline pressure to atmospheric pressure sample container without loss of minor impurities. The sampler will be purged with pipeline CO_2 to remove contaminants prior to sample collection. All sample containers will be labeled with durable labels and indelible markings. A unique sample identification number and sampling date will be recorded on the sample containers. The sample container will be sealed and shipped to an authorized laboratory(s) in Louisiana.

3.5 Laboratory to be used/chain of custody and analysis procedures

Samples will be analyzed by a third party laboratory accredited by the Louisiana Department of Environmental Quality (https://internet.deq.louisiana.gov/portal/divisions/lelap/accredited-laboratories) using standardized procedures for gas chromatography, mass spectrometry, detector tubes, and photo ionization. The sample chain-of-custody procedures described in Section 12.3.3 of the QASP will be employed.

4.0 Continuous Recording of Operational Parameters [40 CFR 146.88(e)(1), 146.89(b) and 146.90(b)]

As required at 40 CFR 146.88(e)(1), 146.89(b), and 146.90(b), GCS will install and use continuous recording devices to monitor:

1. The mass of CO_2 delivered at the transfer point
2. The volume and temperature of CO_2 allocated to each well
3. The pressure at well head
4. The pressure on the injection tubing
5. The pressure at well head on the annulus between the tubing and the long string casing
6. The annulus fluid volume added

4.1 Monitoring location and frequency

GCS will perform the activities identified in Table 4.1 to monitor operational parameters and verify internal mechanical integrity of injection wells. Monitoring will take place at the locations and frequencies shown in Table 4.1.

Following conventional practices at injection sites with multiple wells, the Project Minerva will use a mass flow meter to measure CO_2 mass delivered to the project at the transfer point from the pipeline (same location as CO_2 stream analysis so that any non-CO_2 impurities can be subtracted from the storage accounting). Calibration will be conducted per the manufactures instructions and reported.

Additional flow meters will be installed on flow lines leading to each well to record CO_2 volume and temperature which will serve to guide the allocation of the CO_2 on a per well basis. Calibration will be conducted following the manufactures instructions and reported.

Table 4.1. Sampling devices, locations, and frequencies for continuous monitoring.

Parameter	Device(s)	Location	Min. Sampling Frequency	Min. Recording Frequency
Project mass flow	Coriolis flow meter	Transfer point pipeline to injection project	Continuous	Per Archiver Program
Well head flow volume	Thermally corrected volume flow meter	On injection well, pad	Continuous	Per Archiver Program
CO_2 stream temperature	From flow meter	On injection well pad	Continuous	Per Archiver Program
Injection pressure on tubing	Pressure gauge	On wellhead	Continuous	Per Archiver Program
Annular pressure	Pressure gauge	On wellhead	Continuous	Per Archiver Program
Annulus fluid volume	Direct volume measure	At wellhead	When fluid is added	When fluid is added
Downhole pressure	Quartz pressure gauge	On port in tubing above packer	Continuous (3)	Per Archiver Program
Downhole temperature	Temperature gauge in same devise as pressure	on port in tubing above packer	Continuous (4)	Per Archiver Program
Changes in Rayleigh scattering resulting from distributed strain indicative of wave arrival	DAS optical fiber	Installed on outside of casing	As designed for acoustic survey	As designed for acoustic survey (3)
Changes in Rayleigh scattering indicative of temperature change	DAS optical fiber	Installed on outside of casing	Hourly (3)	Daily

Note (3) set up to sample and record every second during well test procedures

Note (4) set up to sample and record at frequency required during test periods

4.2 Monitoring details

The mass flow meter will be protected against damage by lightning.

Each well will be completed with equipment needed to 1) account for per-well injection mass and pressure as inputs to fluid flow modeling to validate AoR predictions and 2) assure well integrity is maintained.

Well-head pressure and temperature gauges will be installed to detect and record changes in (CO_2-filled) tubing pressure and the casing-tubing anulus (filled with corrosion-inhibited fluid). Replenishment of corrosion-inhibited fluid will occur as needed, and the amounts added will be recorded. A more-rapid-than-normal change in casing-tubing anulus pressure will trigger shut in of injector and inspection of well components until failure is identified.

Downhole quartz pressure gages on wireline readout will provide the required input to models and serve as opportunities for additional calibration of fluid flow models (during injection fall-off tests and when injection is started at each injection well). Downhole pressure monitoring protects the project against over-injection as the near-well environment is cooled and CO_2 becomes denser. The gauge location will be on tubing above the packer where the gauge is protected by corrosion inhibited fluid, with a pass though into the tubing. Pressure gauges will be calibrated according to manufactures instructions and corrected for drift by comparison to tubing deployed gauges during MIT.

Wireline logging will be conducted at a minimum 6 months and 2 years after the start of injection at each well to assess the injection profile (which zones are being used by CO_2). These data will be input the into models. A commercial vendor will be selected to conduct this logging using any of the standard techniques. If the injection profile is not optimum, this log provides input to correct the strategy.

Optical fiber designed for Distributed Acoustic Sensing (DAS) will be used primarily for CO_2 plume tracking, however, it has a valuable secondary role in surveillance of integrity of the casing and cement sheath. Fluid migration produces distributed thermal (DT) and acoustic signals indicative a need for follow on testing. Calibration of DAS and DT surface instrumentation will be performed following the manufacturer's instructions and reported.

The DAS fiber will also be set up to detect changes in frequency of seismicity. The selected vendor will optimize many parameters, including the fiber selection; installation to assure good acoustic coupling; seismic aperture to cover the maximum plume extent at 40 years; and source type, frequency, and installation to create sufficient detection of plume extent at reservoir depth. This is a sparse array focusing on time lapse and designed to history match the model on selected azimuths.

5.0 Corrosion Monitoring

To meet the requirements of 40 CFR 146.90(c), GCS will monitor well materials during the operation period for loss of mass, thickness, cracking, pitting, and other signs of corrosion to ensure that the well components meet the minimum standards for material strength and performance.

GCS will monitor corrosion using coupons and collect samples according to the description below.

5.1 Monitoring location and frequency

Analyzing coupons of the well construction materials used in the well casing and tubing (including any other well parts in contact with CO_2) and inspecting the materials in the coupons for loss of mass, thickness, cracking, pitting, and other signs of corrosion. Loop and coupon details to be specified as part of pipeline and well design. These tests will be performed by qualified vendor on a quarterly calendar basis starting at the end of the first quarter month (March, June, September, December) following authorization and start-up of injection.

5.2 Sample description

GCS anticipates that corrosion coupon (weight loss) technique will be used for monitoring purposes as it is the best known and simplest of all corrosion monitoring techniques (alternative is to use flow line loops). The corrosion monitoring system will be located downstream of all process compression/dehydration/pumping equipment (i.e., at the beginning of the pipeline to the wellhead). This tray of coupons will operate any time injection is occurring. No other equipment will act on the CO_2 past the location of the tray; therefore, this location will provide representative exposure of the samples to the CO_2 composition, temperature, and pressures that will be seen at the wellhead and injection tubing. The holders and location of the system will be included in the pipeline design and will allow for continuation of injection during sample removal. The coupon method involves exposing a sample of material (coupon) to a process environment for a given duration, then removing the specimen for analysis. Coupons will include materials of construction for all elements in contact with the CO_2 stream (Table 1.3). Corrosion analysis will consist of:

1. Sample photography
2. Cleaning
3. Precision weight loss analysis
4. Corrosion rate evaluation
5. Localized corrosion (pitting) analysis

Methods for initial coupon preparation and analysis/evaluation of exposed coupons will follow ASTM G1 - 03(2017) and/or NACE Standard RP0775-2005 Item No. 21017 standards.

Table 5.1. List of equipment coupon with material of construction.

Equipment Coupon	Material of Construction
Surface Piping	"As built" material in contact with CO_2
Wellhead	Chrome14, or "as built" trim material in contact with CO_2
Injection Tubing	Chrome14, or "as built" material in contact with CO_2
Packer	Chrome14, or "as built" trim material in contact with CO_2
Protection Casing below Packer	Chrome14, or "as built" material in contact with CO_2

5.3 Monitoring details

Per § 146.90, GCS will run a casing inspection log (internal and external) to determine the presence or absence of corrosion in the protection (longstring) casing when the tubing is pulled from the well. The log(s) will be compared to those run during construction of the well (§ 146.87). Additional inspection logging may be performed should the coupons show excessive corrosion in excess of design-life criteria.

Alternative testing other than those listed above may be conducted, with the written approval of the Administrator. To obtain approval for alternative testing, GCS will submit a written request to the Administrator setting forth the proposed test and all technical data supporting its use.

6.0 Above Confining Zone Monitoring

GCS will monitor two water-bearing zones in the AoR to meet the requirements of 40 CFR 146.90(d): the lower-most USDW of the Chicot Formation (fresh water) and the part of the Miocene above the Anahuac confining zone (saline water). Leakage detection strategy is different in the two zones, so they are discussed separately.

6.1 USDW monitoring in the lower part of the Chicot freshwater aquifer.

Monitoring location and frequency Table 6.1 shows the planned monitoring methods, locations, and frequencies for ground water quality and geochemical monitoring in the freshwater of the lower Chicot aquifer. The well location and sampling depths will be guided by an airborne conductivity and magnetic survey.

Table 6.1. Monitoring of ground water quality and geochemical changes in the lower Chicot aquifer

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Entire freshwater aquifer	Airborne conductivity and magnetic survey	Over areas of expected groundwater complexity and historical production >AoR	Flown in a grid to produce spatial coverage, as designed by vendor	Prior to project start, at project end, as needed if brine leakage is suspected.
Chicot Aquifer deepest freshwater sand	Groundwater sampling	GW wells 1-2 at injection wells	Over the CO_2 plume	Quarterly for 3 years, then once every 5 years or if an incident occurs
Chicot Aquifer deepest freshwater sand	Groundwater sampling	GW wells 3-5	Over the area of elevated pressure or complexity	Quarterly for 3 years, then once every 5 years or if an incident occurs
Geochemical Modeling	Modeling of fluid mixing to identify diagnostic parameters	Data from GW wells 1-5 and samples from injection zone (IZ) and Above zone monitoring interval(AZMI)	Applicable for entire freshwater aquifer	Once before end of year 3. Used to validate and optimize groundwater monitoring approach.
Chicot Aquifer freshwater sand	Follow on monitoring to incident or anomaly	Near anomaly	Local to anomaly (for example if an existing well fails to isolate the injection zone)	Only as response to anomaly

The goal of groundwater monitoring is to develop a strategy to detect, of either brine or CO_2 leakage from depth into the aquifer, should it occur, using a process known as attribution of signal. This is not simple because many factors are expected to impact groundwater quality in this project area over the coming decades, including change in water levels related to sea level change and climate changes, changes in water production in offsite industrial areas, gradual natural mitigation and dilution of likely past oilfield water contamination events, natural migration of deep basin brines toward the surface in response to basin compaction, change in freshwater chemistry related to salt dissolution at salt domes, and land use changes. The same techniques will be used, if needed, to quantify leakage, assess impacts and validate remediation

Attribution requires:

1. Characterization of injected fluids (described in sections above on Carbon Dioxide Stream Analysis)
2. Characterization of potential deep fluids in the injection zone and overburden that might migrate to the USDW (described below in Above zone monitoring and Injection zone monitoring sections

3. Characterization of the ambient areal and seasonal variability of the USDW (described in this section)
4. Modeling the signal that would allow identification of a mixture of 1 and 2, and separation from naturally driven changes (also described in this section). The same process will support detection of leakage into surface waters and soils, discussed in the ecosystem monitoring section

It is important to collect and analyze components that will be diagnostic, this will depend on the outcomes of initial characterization and monitoring, but Table 6.2 shows the analytes to be evaluated.

Table 6.2. Summary of analytical and field parameters for near surface ground water samples (USDW), Chicot aquifer (Beaumont Formation)

Laboratory Parameters[5]	Analytical Methods	Sensitivity of Method
Dissolved CO_2 gas	Gas Chromatography	+/-2%
Dissolved Methane gas	Gas Chromatography	+/-2%
Dissolved Hydrocarbons (C1-C5)	Gas Chromatography	+/-5% (C1-C3), 10% C4-C5
Alkalinity	Titration	
δC^{13} CO_2	Gas Chromatography with dual inlet isotope ratio mass spectrometer	+/- 0.1 ‰.
δC^{13} Methane	Gas Chromatography with dual inlet isotope ratio mass spectrometer	+/- 0.1 ‰.
C^{14} CO_2	Accelerated mass spectrometry (AMS).	+/- 0.4 pMC
C^{14} Methane	Accelerated mass spectrometry (AMS).	+/- 0.4 pMC
Major elements		
Minor elements including Br, I, Sr		
Isotopic composition of selected major or minor constituents (e.g. $Sr^{87/86}$, S		

Note 5 Parameters will be revised based on initial findings and fluid flow modeling.

GCS will contract to have an airborne conductivity survey designed to collect and interpret the conductivity signal to map and quantitatively model the areas of highest salinity at the surface and in the shallow subsurface. A magnetic survey collected at the same time will screen to detect the casings of any miss-located wells. The survey will be designed by a qualified vendor. Data collection should be planned such that a repeat survey can be conducted in 30 years as part of project closure.

Approximately 5 wells will be drilled and completed to sample fresh water in the USDW. A freshwater sampling point will be located at each of the well pads for the injection wells. Three other freshwater wells will be placed at areas of anomaly or leakage concern, based on the interpretation of the airborne conductivity survey. Well construction will follow Louisiana monitoring well construction requirements. Well elevations will be surveyed. A logging program will be used to set screen over suitable intervals to sample and screen depths recorded. To enhance interpretability, flow zones will not be comingled.

The freshwater wells will be sampled quarterly for three years to detect seasonal variations. For attribution-based detection, pre-injection baseline is not needed. Sample procedures will be optimized to quantify dissolved gases, which includes a flow-through apparatus for collection of intact samples with headspace gas. If wells have free gas (methane is common in groundwater, regionally) sampling will be designed to sample and assess changes in gas production.

Mixing models will be constructed based on integration of the deep fluid composition with the freshwater composition to identify trends and constituents that would be diagnostic of either brine or CO_2 leakage into groundwater, should that occur, and be applicable to any location in the AoR or adjacent regions. Modeling will be completed prior to year 3 and will be used to 1) modify and optimize the groundwater program to the parameters that are most diagnostic and 2) design a response program such that if an incident or allegation of leakage of CO_2 or brine into groundwater occurs, GCS will be ready to sample, assess and report if leakage has occurred and the volume and area impact of the leakage.

A plan will be written to document the response to incident or allegation in case leakage damages fresh water and be designed to be transparent to stakeholders. The plan will include sampling design at the incident site, laboratory processes, analytical processes, and pathway to attribution of the measurements to leakage or to non-leakage causes. The plan will include remediation and remediation validation plans (for applications of leakage detection).

Following the three-year characterization and response-planning period, the sampling frequency at the eight project water wells will be decreased to every 5 years which is sufficient to identify trends and the list of analytes reduced.

6.2 Sampling methods

The sampling system will used to sample and quantify free and dissolved gases and the aqueous phases in equilibrium with theme. Water samples will be collected from groundwater wells according to EPA method SESDPROC-301-R4 - after purging 3 well volumes with a pump, temperature, pH, specific conductivity, dissolved oxygen will be measured in the field. Samples for isotopic analysis of DIC will be collected in 100 ml amber glass bottles with minimized headspace, and 1 drop of biocide (benzalkonium chloride) to eliminate biologic alteration of the sample. Samples will be immediately stored on ice and mailed overnight to a contracted laboratory for analysis of analytes listed in Table 6.2. All samples will be filtered in the field with a 0.45µm filter. Conditions during groundwater sampling will be recorded in the field.

All sample containers will be labeled with durable labels and indelible markings. A unique sample identification number and sampling date will be recorded on the sample containers. The sample container will be sealed and sent to an authorized laboratory.

6.3 Laboratory to be used/chain of custody and analysis procedures

Samples will be analyzed by a third party laboratory accredited by the Louisiana Department of Environmental Quality (https://internet.deq.louisiana.gov/portal/divisions/lelap/accredited-laboratories) using standardized procedures for gas, major, minor and trace element compositions. The sample chain-of-custody procedures described in Section 12.3.3 of the QASP will be employed.)

6.4 AZMI monitoring in the Miocene above the Anahuac confining system.

Above zone monitoring interval (AZMI) wells will be installed in areas of more abundant penetrations, where concern about isolation of the injection zone is higher-than-average. These can also be repurposed by recompletion of existing wells and fitting them with downhole pressure gauges. IZ and AZMI monitoring points can be co-located or engineered as multi-zone completions, if feasible. A change in water composition is not expected in this zone; and water will be sampled once (including for dissolved and free gases) for characterization purposes.

Monitoring location and frequency Table 6.1 shows the planned monitoring methods, locations, and frequencies for monitoring saline formations in the Miocene Above Zone Monitoring Interval (AZMI) above the Anahuac confining system. Modeling shows that pressure is a more robust and more diagnostic leakage detection method in deep confined saline aquifers. Under typical low flow gradients in saline formations, a CO_2 leakage signal is unlikely to propagate far from the leakage point and be chemically undetectable. Leakage of brine from one formation to another is also unlikely to be chemically diagnostic, and if ambient methane or CO_2 is present in the system, CO_2 may not be chemically diagnostic either. GCS will instead measure bottom hole pressure which can be robustly and continuously measured in confined saline zones in deep wells in the 2 AZMI, wells. Pressure trends indicative of leakage can be readily interpreted. If leakage trends are detected, follow up pressure transient testing, logging or geochemical measurements will be conducted to assess the signal.

A two-well array is proposed above the early-stage AoR and mature-stage plume to assure that neither brine nor CO_2 is migrating out of zone.

Table 6.3. Monitoring the Above Zone Monitoring Interval (AZMI) in the Miocene

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
Miocene	Downhole pressure monitoring	Two deep wells	Over area of review	Real time daily read out.
Miocene	Baseline geochemical sampling	Same two deep wells	Over area of review	Once at project start.
Miocene	Follow-on testing if signal is observed	Proximal to anomaly	Proximal to anomaly	Only if anomaly is observed
Miocene	VSP designed for plume tracking will also detect any fluid substitution in the Miocene	Fiber optic in injection well, azimuthal receiver arrays	Azimuthal coverage of the plumes	Annually

The goal of AZMI monitoring is to detect either brine or CO_2 leakage from depth into this saline zone and, should it occur, to provide a barrier to leakage into the USDW. Pressure is the main tool; and geochemical description is used to augment the leakage detection. The presence of gases (CO_2 or hydrocarbons) in the AZMI is the key focus to attribute sources of leakage. Above-zone gas can be a contributor to surface casing vent flow and must be properly attributed to be managed.

The pressure response of each AZMI is measured in idle (no injection and no production) wells in areas within the AoR and near the edge of the CO_2 plume footprint (area inside the plume footprint is coved by time lapse VSP). The wells are located where there is predicted to be higher-than-average leakage risk, such as areas with more abundant existing penetrations. Each AZMI well can be combined with the in-zone wells as dual completions or be separate wells. AZMI monitoring wells may be modified from existing wells.

AZMI wells are isolated within the Anahuac by bridge plug or packers. Wells are designed such that sufficient rat hole exists or a suitable screen is installed to prevent sanding-in by poorly consolidated Miocene sandstones. One or more transmissive Miocene sandstones are selected to serve as AZMI. Higher sensitivity to leakage is obtained by selecting sandstones that have larger areal continuity but are thinner. Selected sandstones are designed to be sparsely perforated, with a packer set above the perforations, and completed with downhole pressure gauge on tubing.

One fluid sampling event is planned. It is important to collect and analyze components that will be diagnostic, and this will depend on the outcomes of initial characterization and monitoring. Table 6.2 details the analytes to be evaluated.

Table 6.4. Summary of analytical and field parameters for fresh ground water samples - Miocene above zone saline aquifer

Parameters [6]	Analytical Methods
Dissolved CO_2 gas by headspace	Gas Chromatography (GC)
Dissolved CH_4 gas by headspace	Gas Chromatography (GC)
Hydrocarbons	Gas Chromatography (GC)
Dissolved inorganic carbon	Combustion
Bicarbonate	Titration
$\delta D\ CH_{24}$	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)
$\delta C^{13}\ CO_2$	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)
$\delta C^{13}\ CH_4$	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)
$C^{14}\ CO_2$	Accelerated mass spectrometry (AMS).
C^{14} Methane	Accelerated mass spectrometry (AMS).
Major cations and trace metals including Sr	inductively coupled plasma-optical emission spectrometry (ICP-OES) and inductively coupled plasma-mass spectrometry (ICP-MS)
Anions including Br, I,	Ion chromatography
Isotopic composition of selected major or minor constituents (e.g., $Sr^{87/86}$, S)	Multicollector-Inductively Coupled Plasma Mass Spectrometer (MC-ICPMS)

Note 6 Parameters will be revised based on initial findings

6.5 Sampling methods (one-time sample)

The system used to sample and quantify free and dissolved gases and the aqueous phases in equilibrium with these gasses will be supplied by a vendor using a Kuster sampler, or equivalent tool. Deep brine sampling protocols are required, and all gasses (not just hydrocarbons) will be assessed. Workflow includes:

1. Purge the casing volume to bring fresh fluids that have not reacted with casing and tubing to the sample point
2. Deploy commercial downhole sampler on slickline to collect a fluid sample at pressure and then close to retain gas phases as sample is transported to the surface
3. Reduce conserved gas volume samples to atmospheric pressure for shipping and analysis
4. Filter and conserve samples following protocols for brine sampling.

5. Label sample containers with durable labels and indelible markings - a unique sample identification number and sampling date will be recorded on the sample containers.
6. Send sealed sample container to an authorized laboratory.

Repeat sampling is not needed. If an anomalous pressure signal is detected, head spaced gas analysis plus pressure transient testing should be sufficient to detect any CO_2 leakage.

6.6 Laboratory to be used/chain of custody and analysis procedures

Samples will be analyzed by a third party laboratory accredited by the Louisiana Department of Environmental quality (https://internet.deq.louisiana.gov/portal/divisions/lelap/accredited-laboratories) using standardized procedures for gas, major, minor and trace element compositions.. The sample chain-of-custody procedures described in Section 12.3.3 of the QASP will be employed.)

7.0 External Mechanical Integrity Testing (MIT)

GCS will conduct at least one of the tests presented in Table 7.1 periodically during the injection phase to verify external mechanical integrity as required at 146.89(c) and 146.90.

7.1 Testing location and frequency

GCS will perform an annual external mechanical integrity log on each injection well. Preferred testing will be performed using a temperature survey. The principal requirement for running temperature logs is that the well be shut in long enough so that temperature effects related to well construction can dissipate, leaving a relatively simple temperature profile. Experience has shown that 36 hours is usually sufficient for the shut-in time period. Temperature survey data will be developed from the optical fiber attached to each injection well protection (longstring) casing.

Should the optical fiber not be functioning, the survey will be performed via a wireline truck and the temperature survey will be run over the entire interval of cemented casing. Note that to be effective, temperature logging tools must have good thermal coupling to the borehole environment, which means that they are not generally useful in gas or air-filled boreholes. Depending on phase of the carbon dioxide in the well, this may require that the wellbore be displaced with water or bine and allowed to thermally stabilize prior to logging. When possible, the sonde will be calibrated to a known temperature. The injection well will be logged from the surface downward, lowering the tool at a rate of no more than 30 feet per minute, which represents a practical balance between the tool response time and normal field time constraints. Note that slower logging speeds provide increasing detail. The temperature log should include both an absolute temperature curve and a differential temperature curve. A correlation log(s) should be recorded in track 1 (such as casing collar locator or gamma ray), and the two temperature curves recorded in tracks 2 and 3. The temperature log should be scaled at or about 20° F (10° C) degrees per track and the differential curve scaled in any manner appropriate to the logging equipment design, but it must be sensitive enough to readily indicate thermal anomalies.

Testing will be scheduled to be performed on an approximate annual basis, within +/-45 days of the prior years' test. GCS will notify the Director ahead of testing should a testing event fall outside of the +/-45 day window. Should a wireline truck be needed to run the surveys, testing for each well may be consolidated to a common timetable.

Alternate logging will consist of either a tracer survey, such as either a radioactive tracer or oxygen-activation log, or noise log. GCS will notify the Director ahead of testing should an alternate testing method be employed in one or more of the injection wells.

Table 7.1. Mechanical integrity tests

Test Description	Location
Temperature Survey	Each Injection Well
Temperature Survey	Monitoring Well

7.2 Testing details

Using temperature survey data from the optical fiber attached to each injection well protection (longstring) casing in each injection well is the simplest and preferred testing methodology for the demonstration of external integrity. Data from the optical fiber will be collected starting at cessation of injection and then accrued at increasing time intervals out to approximately 36 hours of shut in. Should the optical fiber not be functioning, the temperature survey will be performed via a wireline truck.

Subsequent temperature surveys will be compared to the baseline and prior surveys in each injection well. Deviations from a predictable geothermal gradient (initial survey) indicate the effects of injection. Within the Frio Formation, deviations will occur in those sands receptive to flow. Deviations above the Anahuac Shale are anomalies. These may take the form of a nearly constant temperature between strata separated over a significant interval. In the case of the optical fiber temperature data, or if more than one log is run from a wireline truck, these anomalies are likely to "grow" as the other parts of the temperature profile returns toward the natural geothermal gradient. In addition, those areas with active flow will reach a stable temperature more quickly than other areas (zones of historical flow).

If there are unresolved temperature anomalies that cannot be explained, a failure of mechanical integrity of the injection well may be indicated. In such a case, additional logging may be necessary to show whether a loss of mechanical integrity is occurring in that injection well. Depending on the nature of the suspected movement, radioactive tracer, noise, oxygen activation, or other logs approved by the Director may be required to further define the nature of the fluid movement. Identification of flow behind the casing is always made from long-term shut-in logs. The resolution of long-term shut-in logs for identifying the presence of flow is greater than that of logs made during injection. The temperature gradient from top to bottom within a well which has been injecting for some time is very shallow. The temperature at the injection zone may be only a few degrees different from that at the surface. The presence of a flow behind the casing will result in a fractional change in this gradient which will be proportional to the ratio of the flow rates within and outside the tubing. Therefore, only a rather substantial flow can be identified using logs made during injection.

8.0 Pressure Fall-Off Testing

GCS will perform pressure fall-off tests during the injection phase as described below to meet the requirements of 40 CFR 146.90(f).

8.1 Testing location and frequency

GCS will perform a baseline pressure falloff test using brine or water mixed with a clay stabilizer in each injection well. This will allow for baseline characterization of the transmissibility of the Frio at each injection well. The initial pressure falloff testing will be repeated using carbon dioxide within the first 60 days of injection operations. This will allow for comparison to the baseline test with the change in the injection fluid from brine water to carbon dioxide.

A subsequent pressure falloff test will be performed within +/-45 days of the 2-1/2 year anniversary of the start of carbon dioxide injection and within +/-45 days of the 5 year anniversary of the startup of injection. Thereafter, a pressure falloff test will be performed in each injection well within +/-45 days of each subsequent 5 year anniversary of the previous pressure test throughout the duration of the injection project. A final pressure falloff test will be run at the cessation of injection into each injection well.

8.2 Testing details

Testing procedures will follow the methodology detailed in EPA Region 6 UIC Pressure Falloff Testing Guideline-Third Revision (August 8, 2002). Bottomhole pressure measurements near the perforations are preferred due to phase changes within the column of carbon dioxide in the tubing. A surface pressure gauge may also serve as a monitoring tool for tracking the test progress.

The downhole pressure gauge can be either installed as part of the completion or can be deployed via a wireline truck. If a wireline truck deployed gauge is used, the wireline should be corrosion resistant (such as MP-35 line) and the deployed gauges should consist of a surface read-out gauge with a memory backup. Gauge specifications should be as follows or similar to those shown in Table 8.1.

Table 8.1 Pressure Gauge Information

Pressure Gauge	Property	Value
Surface Readout Pressure Gauge	Range Resolution	0 – 10,000 psi/200 ºC +/-0.02 psi/0.005 ºC
	Accuracy	+/-0.024% of full scale (+/-2.4 psi/+/-0.25 ºC)
	Manufacturer's Recommended Calibration Frequency	Minimum Annual
Memory Pressure Gauge	Range Resolution	0 – 10,000 psi/200 ºC +/-0.02 psi/0.005 ºC
	Accuracy	+/-0.024% of full scale (+/-1.4 psi/0.25 ºC)
	Manufacturer's Recommended Calibration Frequency	Minimum Annual

General testing procedure is as follows (presumes that a wireline deployed unit is used for the testing, note that dedicated downhole monitoring gauge may be used if installed on the injection well):

1. Mobilize wireline unit to the injection well and rig up on wellhead.
2. Rig up a wireline lubricator containing a calibrated downhole surface-readout pressure gauge (SRO) with memory gauge installed in the tool string as a backup, to the adapter above the crown valve. Each gauge should have an operating range of 0 - 10,000 psi. Reference the gauge to kelly bushing (KB) reference elevation and the elevation above ground level.
3. Open crown valve, record surface injection pressure, and run in hole with SRO to just above the shallowest perforations in the completion while maintaining injection at a constant rate. Steady rates of injection should be maintained for at least 24 hours ahead of the planned shut-in of the injection well. Any offset injection well should be either shut-in or maintaining a constant rate of injection for the entire duration of the testing. This will minimize any cross-well interference effects.
4. With the SRO positioned just above the perforations, monitor the bottom-hole injection pressure response for ±1 hour to allow the gauge to stabilize (temperature and pressure stabilization). Ensure that the injection rate and pressure are stable.
5. Cease injection as rapidly as possible (controlled quick shut-in); close the control valve and the manual flowline valve at well site (start with the valve closest to the wellhead so

that wellbore storage effect in early time is minimized). Conduct the pressure fall-off test for approximately 24 hours, or until bottomhole pressures have stabilized.

6. Lock out all valves on the injection annulus pressure system so that annulus pressure cannot be changed during the falloff period. Ensure that valves on flow line to the injection well are closed and locked to prevent flow to the well during the falloff period.
7. After 24 hours, download data and make preliminary field analysis of the falloff test data with computer-aided transient test software to estimate if or when radial flow conditions might be reached. If sufficient data acquisition is confirmed, end falloff test. If additional data is required, extend falloff test until radial flow conditions are confirmed. After confirmation of sufficient data acquisition, end falloff test.

Pull SRO tool up out of the well at 1,000 ft increments and allow the gauge to stabilize (5 minutes each stop). Record stabilized temperature and pressure. Repeat the process to collect stabilized pressure data (5 minute stops) at 1,000 ft intervals and in the lubricator.

9.0 Carbon Dioxide Plume and Pressure Front Tracking

GCS will employ direct and indirect methods to track the extent of the carbon dioxide plume and the magnitude of elevated pressure during the operation period to meet the requirements of 40 CFR 146.90(g).

9.1 Plume monitoring location and frequency

Table 6.4 presents the 4-D seismic methods that GCS will use to monitor the position of the CO_2 plume. No fluid sampling of the plume in the injection zone is planned.

Quality assurance procedures for these methods are presented in 12.2.4 of the QASP.

9.2 Plume monitoring details

Substitution of CO_2 for brine in the Frio Formation at project depths is well documented to produce a strong change is acoustic impendence that can be detected by many time lapse seismic methods. Azimuthal 4-D VSP is selected as the optimal geometry, with sparse walk-away type array of acoustic source sites oriented along the maximum and minimum orientations of the modeled plume as it approaches stabilization. In this array type, DAS fiber is installed in cement behind casing, sending signal to an interrogator to detect acoustic signal; signal produced by radial arrays of well-coupled pads (e.g. an excavated pit filled with a cement pad) on which sources can be repeatably bolted. The following considerations lead to selection of this method for plume tracking:

1) Key issue is radial extent of CO_2 plume - azimuthal 4-D VSP is ideal for tracking plumes with a radial geometry
2) Prevalence of wetlands in the area precludes use of surface 3-D on grounds of poor access and risk of excessive environmental damage during laying out source arrays.

Also shifting climate could change surface water distribution and therefore source distribution, damaging repeatability.

3) Permanent installations for acoustic sources optimize repeatability, which is critical in time laps tracking
4) The availability and demonstrated effectiveness of DAS fiber as an acoustic receiver favors this type of installation.
5) The same arrays will be used into the PISC period

Vendors will be contracted to design the area and processing flow, install DAS fiber, supply interrogators(s) for both temperature and acoustic signals, design the source arrays including frequency and coupling to assure good signal-to-noise to detect impedance contrast at depth and thickness modeled, and data analysis. Report from azimuthal VSP will be CO_2 migration along the selected azimuths. These measurements can be plotted against equivalent model outputs and be used to validate or correct as needed the fluid flow model and plume tracking predictions to satisfy the requirements at 40 CFR 146.90(g).

In addition, the use of fiber will allow very wide aperture of the acoustic array and so include surveillance of Miocene strata above the CO_2 plume to provide that no out-of-zone CO_2 migration is occurring in this area.

Advanced interpretation of pressure transient testing may be used to acquire complementary information about the CO_2 plume geometry. Table 1.10 details the use of VSP as the plume monitoring technology. Table 1.11 affirms that no geochemical methods are deployed for plume tracking.

Table 9.1. Plume monitoring activities.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
PLUME MONITORING USING VSP				
Multiple zones of Frio Formation	VSP	Fiber optic in injection well, azimuthal receiver arrays	Azimuthal coverage of the plumes	Annually

Table 9.2. Summary of analytical and field parameters for fluid sampling in the injection zone.

Parameters	Analytical Methods
No fluid collection planned in plume	

9.3 <u>Pressure-front monitoring location and frequency</u>

Table 9.1 presents the well-based methods that GCS will use to monitor the magnitude of pressure change and validate model of the AoR to meet the to meet the requirements of 40 CFR 146.90(g).

These well may be recompletions of suitable existing wells, dual completions with AZMI wells, or stand-alone new drills. Pressure will be measured continuously and reported daily.

One fluid sampling event is planned. The same methods and sampling analytics will be used in both the Frio Formation and Miocene interval (Table 6.2).

9.4 Pressure-front monitoring details

Two wells will be sparsely perforated over the major permeable zones of the Frio Formation. A packer will be set above the perforations and completed with downhole pressure gauges on tubing.

Table 1.12 sets forth the primary monitoring activities.

Table 9.3. Pressure-front monitoring activities.

Target Formation	Monitoring Activity	Monitoring Location(s)	Spatial Coverage	Frequency
PRESSURE MONITORING in the Injection zone				
Perforated well in brine-bearing part of AoR	Pressure measurement with downhole gauges	2 wells outside of CO_2 plume area	Pressure is diffusive, sample at representative points	Daily

10.0 Environmental monitoring at the surface

To meet the requirements of 40 CFR 146.90(h), GCS will employ direct sampling and process-based analytical methods such that any brine or CO_2 leakage signal in soil or surface water can be quickly and effectively detected and isolated from background. This approach is similar to that proposed for groundwater but adapted to these sampling locations.

The Project Minerva area is expected to be dynamic in terms of CO_2 production and uptake from active environments including plant and animal activities, wetland bottom sediments, and intermittently saturation soils. It is also used for grazing and other activities which are likely to change over time. Salinity variations are also present in the area as a result of past oilfield activities and from natural discharge of fluids from depth and around salt domes. Given this high background variation, concentration-based detection methods are unlikely to be able to detect/distinguish Project Minerva-related leakage. We propose an anomaly response program to be deployed on an as-needed basis if an incident or anomaly with possible surface impact occurs.

10.1 Environmental surface monitoring location and frequency

Approximately 10 soil monitoring locations (soil gas wells) and 10 surface water monitoring stations will be sufficient to provide representative samples of the geochemical signatures of ecosystems within the AoR. For 2 years soil gas wells will be sampled seasonally (4 times) and analyzed for gas CO_2, O_2, N_2, CH_4, C1-C5 hydrocarbons, $\delta^{13}C$ and ^{14}C of CO_2 and CH_4 and δD of CH_4. A similar sampling schedule will be applied to surface water assessment.

Soils will be collected during the installation of soil gas monitoring stations and may also be acquired at additional sites using hand-auger as informed by the conductivity survey. Soils will be tested for salinity according to United States Department of Agriculture methods to identify and characterize background types and occurrences of salinity and devise methods for attributing the source of salinity in the surface environment, whether natural for from industrial sources

At the end of 2 years, protocols for detection of leakage signal will be developed for soil gas, sediments, and surface water, following the same methods as used for groundwater attribution. A process-based method using ratios of CO_2, O2, N2, CH4, can be used across all these environments to normalize diurnal and seasonal variations in soil CO_2 that result from variations in soil respiration rates, possible because these ratios remain stable with reference to the respiration line. Any composition that plots to the right of the respiration line would require further assessment using isotopes $\delta^{13}C$ and ^{14}C of CO_2 and CH_4 and δD of CH_4..

11.0 Sampling/Analytical Procedures and QA/QC

This section provides details on sampling and analytical procedures and associated QA/QC requirements necessary to ensure valid data are obtained from the primary measurements to be conducted during the test. Details on the methods to be used are listed in Table 11.1.

Gas, water and soil samples will be collected into the appropriate sample containers, properly preserved and shipped to the contract laboratory for compositional analysis with reference to methodologies outlined in Table 6.2, Table 6.4 and Table 11.1.

For all samples collected, general information for each sampling station location will be recorded, including project name, borehole designation, borehole total depth, date and time of completion, borehole GPS location information, and field personnel information.

Table 11.1 Soil gas parameter and analysis method summary

Soil Gas Parameter	Analysis method	Method sensitivity
CO_2, N_2, O_2,	Gas Chromatography (GC)	+/- 2 %.
CH_4, C_2-C_4	Gas Chromatography (GC)	+/- 5 %.
C_5-C_6	Gas Chromatography (GC)	+/- 10 %.
$\delta^{13}C$ of CO_2	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)	+/- 0.3 ‰
$\delta^{13}C$ of CH_4	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)	+/- 0.3 ‰.
δD of CH_4	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)	+/- 5 ‰.
^{14}C of CO_2	Accelerated mass spectrometry (AMS).	+/- 0.4 pMC
^{14}C CH_4	Accelerated mass spectrometry (AMS).	+/- 0.4 pMC

11.1.1 Soil Gas Sampling Station Construction

Geoprobe, hand auguring, or hollow-stem auger drilling (continuous-flight) by a contracted drilling company will be used to create a borehole for soil gas well installation.8-cm boreholes drilled with a hollow stem auger by a contracted drilling company will be drilled to a depth of 1 to 1.5 meters. Sampling stations will be installed in permeable soil layers and can be sampled for gas analysis whether these depths are saturated or dry using methods outlined in Table 11.2. Sample tubes will be comprised of 3 mm diameter stainless steel tubing fitted at one end with Geoprobe® 15-cm vapor implant screens. Each screen will be fitted to well tubing with Swagelok® gas-tight connectors. Sample depth intervals will be filled with a quartz-sand filter pack placed in the well annulus and isolated with bentonite. The bentonite will be used to backfill between depth intervals assuring the integrity of each sampling interval. Each well will be sealed at the top with a no-flow Swagelok® quick-connect stem which restricts exchange of gas between the gas well and the atmosphere. Gas wells will be protected at ground surface and capped.

General information for each sampling station location will be recorded, including project name, borehole designation, borehole total depth, date and time of completion, borehole GPS location information, and field personnel information.

Table 11.2 Methodologies for obtaining samples for surface environmental monitoring

Sampling Approach	EPA Method(s)	Description
Soil gas sampling station installation and sampling protocols	LSASDPROC-307-R4	Specific procedures methods and considerations to be used and observed when installing sampling infrastructure and collecting soil gas samples.
Soil pore water sampling for dissolved gases	LSASDPROC-513-R4 SESDPROC-513-R2	Operating procedure for obtaining a pore water sample from soil or sediment
Dissolved gases from water samples.	RSKSOP-175RSKSOP-175-2	Sample preparation and calculations for dissolved gas analysis in water samples using a GC headspace method
Surface water sample collection	SESDPROC-201-R3	General and specific procedures, methods, and considerations to be used and observed when collecting surface water samples for field screening or laboratory analysis.
Soil sampling	LSASDPROC-300-R4	Specific procedures, methods, and considerations to be used and observed when collecting soil samples for field screening or laboratory analysis.
Soil analysis	Corwin, Dennis L., B. A. Stewart, and T. A. Howell. "Soil salinity measurement." *Encyclopedia of Water Science. Marcel Dekker, New York, NY, USA* (2003): 852-860.	USDA method for the measurement of soil salinity and quantification of the total salts present in the liquid portion of the soil.
Surface water analysis	Clean Water Act Analytical methods 120.1, 150.2, 300.0, 310.2, 200.2,200.7 and those listed in Table 5.	Approved chemical methods for inorganic non-metals and metals and isotopic analysis. Preservation of samples according to Laboratory Operations and Quality Assurance Manual (ASBLOQAM).

11.2 Sampling/Analytical Procedures and QA/QC

Sediment sample information will be recorded in the field, including the top and bottom depths, the depth from which sediments are sampled, and the drilling system used. Sediment lithology will be described and noted in the field and will be documented with photographs. Sediment splits, approximately 0.5 to 1 kg of sample per 10 cm of core (or another suitable interval based on sediment lithology), will be removed and stored in 500 ml HDPE containers transported to the contracted laboratory, as warranted. Soils will be analyzed by a contracted laboratory using soil solution extracts at higher than normal water contents. Anions, pH, electrical conductance, (e.g. salinity) +/- other analytes of importance for attribution as informed by the reservoir and groundwater characterization will be analyzed and a plan for attribution of any potential contamination from industrial activities (past or future) will be devised.

11.3 Surface water sampling

Surface water is abundant, with freshwater and saltwater coastal marshes, rivers, lakes, bayous, tidal channels, and canals. Surface water will be sampled by either grab samples directly into the collection bottle or through peristaltic pump. Samples will be filtered and preserved according to protocol for each analyte as described in Table 6.2 and Table 11.2. The operating procedure for field sampling quality control (SESDPROC-011) will be followed as well as preservation requirements for surface water samples as outlined in USEPA Region 4 Analytical Support Branch Laboratory Operations and Quality Assurance Manual (ASBLOQAM).

Gas and water samples will be collected into the appropriate sample containers, properly preserved, and shipped to the contract laboratory for compositional analyses with reference to methodologies outlines in Table 11.3.

This section provides details on sampling and analytical procedures and associated QA/QC requirements necessary to ensure valid data are obtained from the primary measurements to be conducted during the test.

Table 11.3 Gas sampling methods

Parameter	Analysis method	Method sensitivity
CO_2, N_2, O_2,	Gas Chromatography (GC)	+/- 2 %.
CH_4, C_2-C_4	Gas Chromatography (GC)	+/- 5 %.
C_5-C_6	Gas Chromatography (GC)	+/- 10 %.
$\delta^{13}C$ of CO_2	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)	+/- 0.3 ‰
$\delta^{13}C$ of CH_4	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)	+/- 0.3 ‰.
δD of CH_4	Gas chromatography combustion isotope ratio mass spectrometry (GC/C/IRMS)	+/- 5 ‰.
^{14}C of CO_2	Accelerated mass spectrometry (AMS).	+/- 0.4 pMC
^{14}C CH_4	Accelerated mass spectrometry (AMS).	+/- 0.4 pMC

11.4 Quality Assurance and Surveillance Plan

Quality assurance procedures for these methods are presented in 12.2.4 of the QASP.

11.5 Environmental surface monitoring Quality Management

To satisfy the project objectives, the quality and transparency data collection, data analysis, and reporting will be managed at each stage.

11.6 Data Review and Validation

Data will be reviewed by the project operator or designee on an ongoing basis as the data are collected in the field and as results are received from the laboratory. Data review will consist of (for example):

- Verifying that data collection and calibrations/QC checks are complete and fully documented
- Examining raw data values and trends for consistency and reasonableness
- Making comparisons between related measured parameters and calculated values for agreement within reasonable expectations
- Flagging incomplete, invalid, or suspect data and documenting the reason for the flag
- Initiating investigative or corrective actions as needed.

All valid data will be included in the data analysis and reflected in the reported results. Suspect data may or may not be considered or may receive special treatment as will be specifically indicated. The impact on data quality of any problems or issues that arise will be fully assessed, documented, and reported. Any limitations on the use of the resulting data will be fully assessed and reported.

11.7 Sample Handling and Custody

11.7.1 Chain-of-Custody (COC)

Proper sample handling and custody procedures ensure the custody and integrity of samples beginning at the time of sampling and continuing through transport, sample receipt, preparation, and analysis. The COC [QASP Section 12.3.3] is used to document sample handling during transfer from the field to the laboratory. The sample number, location, date, changes in possession and other pertinent data will be recorded in indelible ink on the form. The sample collector will sign the COC and transport it with the sample to the laboratory. At the laboratory, samples are inventoried against the accompanying COC. Any discrepancies will be noted at that time and the COC will be signed for acceptance of custody.

11.7.2 Sample Handling and Labeling

Samples will be labeled on the container with an indelible, waterproof marker. Label information will include site identification, date, sampler's initials, and time of sampling. The COC form will accompany all sets of sample containers.

Following collection, samples will be preserved and transported to the appropriate analytical laboratory for analysis under the conditions designated by the method handling criteria outlined in methods shown in Table 11.2 until analysis.

11.8 Audits, Quality Assessment and Response Action

The technical systems audit is intended to ensure that the sampling, data collection and analysis, QA/QC measures, and documentation are executed in accordance with this plan and that the quality impact of any deviations from the plan is fully assessed and documented. To this end, the internal reviewer will prepare an audit checklist including all key elements of this plan and, to the extent possible, systematically verify in the field that each key element is conducted according to plan.

The audit of data quality will consist of verifying that reported results are fully supported by the data collected and traceable back to their sources in the raw data. Additionally, it must be verified that all required QA/QC is complete and documented for each data source, and that calculations are correct and results and uncertainties correctly reported.

11.9 Data Management and Records

GCS will be responsible for ensuring that all electronic and hard copy data, forms, and logs are accounted for, properly completed, and stored in project files.

The level of documentation will be such that a third party may reproduce the results from the raw data. This requires that all necessary information be documented, and that the documents are organized and maintained such that the information may be practically retrieved and made use of.

Documentation will consist of instrument and other digital files, hard copy field log sheets, calibration certificates, laboratory reports, etc. All documents will ultimately be stored in electronic form; however, hard copy log sheets will be retained on file. An electronic data package will be compiled containing project documentation sufficient to allow a third party to reproduce the results and organized in such a manner that this may be done without undue effort.

11.10 Management of Change

Changes or deviations from this plan may be necessitated by field conditions, unexpected events, observations, or opportunities to improve the results as determined by the project operator. In such events, the reason for the change, and the new measures implemented will be documented in a note to the project log (if the change is minor) or deviations memorandum. This will include an assessment of the impact of the change on data quality. Verification of this will be part of the internal field and data audits.

Comprehensive deviations memorandum will be prepared including an overall assessment of all changes on data quality. Any new or revised procedures will be documented. Significant deviations and their impact on data quality will also be addressed in the final report.

12.0 APPENDICES

12.1 APPENDIX 1: Class VI Injection Well: Quality Assurance and Surveillance Plan

12.2 Project Management

12.2.1 A.1. Project/Task Organization

12.2.1.1 A.1.a/b. Key Individuals and Responsibilities

The Minerva Project is led by Gulf Coast Sequestration (GCS) and includes participation from several subcontractors. The Testing and Monitoring Activities responsibilities will be shared between GCS and their designated subcontractors and conducted in the following subcategories:

I) CO_2 Stream Analysis Surface Sampling
II) Continuous recording of operational parameters
III) Corrosion monitoring
IV) Above Confining zone monitoring
IV) External Mechanical Integrity Testing (MIT)
V) Pressure fall-off testing
VI) Carbon Dioxide plume and Pressure from tracking
VII) Environmental monitoring at the Surface

12.2.1.2 A.1.c. Independence from Project QA Manager and Data Gathering

The majority of the physical samples collected, and data gathered as part of the MVA program is analyzed, processed, or witnessed by third parties independent and outside of the project management structure.

12.2.1.3 A.1.d. QA Project Plan Responsibility

GCS will be responsible for maintaining and distributing official, approved QA Project Plan. GCS will periodically review this QASP and consult with US EPA if/when changes to the plan are warranted.

12.2.1.4 A.1.e. Organizational Chart for Key Project Personnel

Figure 12.1 shows the organization structure of the project. GCS will provide to the UIC Program Director a contact list of individuals fulfilling these roles.

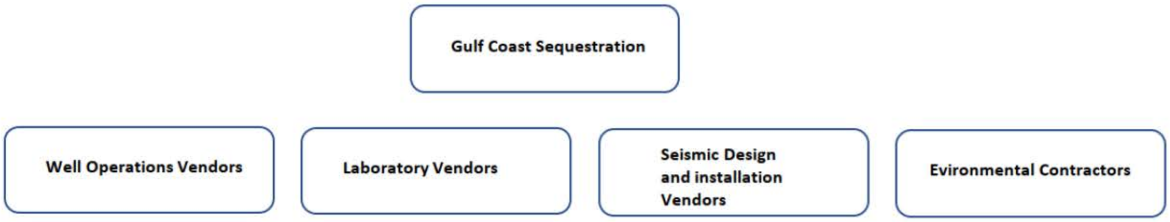

Figure 12.1 GCS Organization

12.2.2 A.2. Problem Definition/Background

12.2.2.1 A.2.a. Reasoning

The M&T program is responsive to the requirements of the Class VI specifications and employs best practices developed in similar CO_2 storage projects.

12.2.2.2 A.2.b. Reasons for Initiating the Project

The M&T project goals are to comply with the Class VI protocols, to document via targeted data collection that the predictions made during characterization and modeling are correct and that CO_2 and brine in the injection zone will be isolated from USDW, surface and atmosphere.

12.2.2.3A.2.c. Regulatory Information, Applicable Criteria, Action Limits

The Class VI Rule requires owners or operators of Class VI wells to perform several types of activities during the lifetime of the project in order to ensure that the injection well maintains its mechanical integrity, that fluid migration and the extent of pressure elevation are within the limits described in the permit application, and that USDWs are not endangered. These monitoring activities include mechanical integrity tests (MITs), injection well testing during operation, monitoring of ground water quality, tracking of the CO_2 plume and associated pressure. This document details both the measurements that will be taken as well as the steps to ensure that the quality of all the data can be used with confidence in making decisions during the life of the project.

12.2.3 A.3. Project/Task Description

12.2.3.1 A.3.a/b. Summary of Work to be Performed

Table 12.1 Summary of Testing and Monitoring describes the Testing and Monitoring tasks, responsible parties, locations and testing frequency.

Table 12.1 Summary of Testing and Monitoring

Activity	Location(s)	Method	Analytical Technique	Lab/Custody	Purpose
Carbon dioxide stream analysis	Central sampling point	High pressure vessel	Standard gas analysis at lab	As provided by lab	Monitor injectate for accounting
Injection mass	Central sampling point	Mass flow meter,	Mass Measurement	NA	Measurement of CO_2 mass delivered to site
Volume in each well	Distributed meters at injection wells	distributed temperature – corrected meters at wells	Volume measurements	NA	Volume of CO_2 distributed to each well
Injection pressure	Wellhead gauge each injection well	Pressure and temperature gauge	Direct measurement	NA	Surface pressure on tubing
Annular pressure	Wellhead gauge each injection well	Pressure and temperature gauge	Direct measurement	NA	Surface pressure on tubing
Downhole pressure/ temperature	Downhole gauge on wireline each injection well	Downhole pressure and temperature gauge	Direct measurement	NA	Pressure downhole near sand face injection zone
Wireline logging	Conducted at each injection well	Injection profile log	Provided by vendor	NA	Model input showing which zones are accepting CO_2.
Corrosion monitoring	Holder at each injection well	Weight loss	ASTM G1 - 03(2017) and/or NACE Standard RP0775-2005 Item No. 21017 standards	As provided by lab	Monitor corrosion

Activity	Location(s)	Method	Analytical Technique	Lab/Custody	Purpose
Chicot water sampling	8 selected freshwater wells	Water sampling with intact gas	Laboratory analysis	As provided by lab	Document groundwater chemistry
Pressure monitoring in Miocene Above-zone monitoring interval	2 selected wells	Downhole pressure and temperature gauge, perforated in Miocene interval (s)	Direct measurement	NA	Pressure downhole above confining system
External Mechanical integrity	Each injection well	Temperature survey	Analysis of thermal anomaly	NA	Detect leakage in casing
Pressure fall-off testing	Each injection well	EPA Region 6 UIC Pressure Falloff Testing Guideline-Third Revision (August 8, 2002)	EPA Region 6 UIC Pressure Falloff Testing Guideline-Third Revision (August 8, 2002)	NA	Assess injectivity
In-zone pressure tracking	2 selected wells	Downhole pressure and temperature gauge, perforated in Frio interval (s)	Direct measurement	NA	P In-zone pressure tracking
CO_2 plume tracking	Fiber in wells, sources on azimuths	Vertical seismic profile (VSP)	VSP	NA	CO_2 plume tracking
Environmental monitoring	Selected sites in AoR	Soil gas and surface water sampling	GC and laboratory analysis	As provided by lab	Environmental monitoring

Table 12.2 Instrumentation Summary

Monitoring Location	Instrument Type	Monitoring Target (Formation or Other)	Data Collection Location(s)	Explanation
CO_2 Central CO_2 handling	Mass flow meter	Monitor injectate for accounting	SCADA	Mass and density are basic surveillance techniques
	Sampling port	Monitor injectate for accounting	Via lab	Identify unacceptable impurities, CO_2 accounting
Injection Wells 1,2,3, 4	Temperature corrected volume meter	Monitor injectate for each well	SCADA	For input to models
	Wellhead pressure gauge on tubing	Safely and compliance	SCADA	Safely and compliance
	Wellhead pressure gauge on annulus	Safely and compliance	SCADA	Safely and compliance
	Downhole pressure and temperature gauge	Frio	SCADA	For input to models

Monitoring Location	**Instrument Type**	**Monitoring Target (Formation or Other)**	**Data Collection Location(s)**	**Explanation**
	Fiber optic DAS and DT	Whole section	Dedicated server, designed as part of VSP array	CO_2 plume tracking, well integrity
In-zone monitoring Wells 1 and 2	Well corrosion management program	Prevent corrosion		Prevent corrosion
	Wellhead pressure gauge on tubing	Safely and compliance	SCADA	Safely and compliance
	Downhole pressure and temperature gauge	Frio	SCADA	For input to models
AZMI monitoring Wells 1 and 2 [Insert Other location]	Well corrosion management program	Prevent corrosion		Prevent corrosion
	Wellhead pressure gauge on tubing	Safely and compliance	SCADA	Safely and compliance

Monitoring Location	Instrument Type	Monitoring Target (Formation or Other)	Data Collection Location(s)	Explanation
	Downhole pressure and temperature gauge	Miocene	SCADA	To show no out of zone fluid loss
VSP walk-way source stations	Stable platform for source relocation	Whole section	Dedicated server, designed as part of VSP array	Sources of VSP
Groundwater wells	Relocatable pump and groundwater level monitoring system	Chicot Aquifer	Environmental data storage	Installed system or relocated to each of the wells
Soil and surface water sampling locations	Shallow wells or marked sample points	Near surface water and gas	Environmental data storage	Details designed by at next stage of project development

12.2.3.2 A.3.c. Geographic Locations

See Figure 2.1.

12.2.3.3 A.3.d. Resource and Time Constraints

No additional resource or time constraints have been identified for the testing and monitoring plan beyond project funding levels and the proposed timeline.

12.2.4 A.4. Quality Objectives and Criteria

The objective of the Quality Assurance Plan is to validate the necessary steps and attention to detail to ensure that the overall integrity of the Testing and Monitoring Plan is implemented, measured and verified. The QASP is the mechanism by which the UIC Program Director and by extension the public has confidence that the rigor of the Testing and Monitoring Plan is being implemented.

12.2.4.1 A.4.a. Performance/Measurement Criteria

To be completed as vendor selection and onboarding is advanced and relevant scope of works are adopted and implemented.

Table 12.3 Summary of Analytical Parameters for CO_2 Stream

Parameters	Analytical Methods[1]	Detection Limit/Range	Typical Precisions	QC Requirements
Carbon Dioxide (CO_2)	ISBT 2.0 Caustic absorption Zahm-Nagel ALI method SAM 4.1 subtraction method (GC/DID) GC/TCD	Note 2	Note 2	Note 2
Water (H_2O)		Note 2	Note 2	Note 2
Oxygen (O_2)	ISBT 4.0(GC/DID) GC/TCD	Note 2	Note 2	Note 2
Nitrogen (N_2)	ISBT 4.0(GC/DID) GC/TCD	Note 2	Note 2	Note 2
Hydrogen Sulfide (H_2S)	ISBT 14.0 (GC/SCD)	Note 2	Note 2	Note 2
Argon (Ar)		Note 2	Note 2	Note 2
Sulfur dioxide (SO_2)	ISBT 10.1 GC/FID)	Note 2	Note 2	Note 2
Methane (CH_4)	ISBT 10.1 GC/FID)	Note 2	Note 2	Note 2
Total hydrocarbons (C2H6, C3H8+)	ISBT 10.0 THA (FID)	Note 2	Note 2	Note 2
Hydrogen (H_2)		Note 2	Note 2	Note 2

Carbon Monoxide (CO)	ISBT 5.0 Colorimetric ISBT 4.0(GC/DID	Note 2	Note 2	Note 2
COS		Note 2	Note 2	Note 2
Nitrogen Oxides (any (NO_x)	ISBT 7.0 Colorimetric	Note 2	Note 2	Note 2
Glycol		Note 2	Note 2	Note 2

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.
Note 2. These details to be negotiated with the selected lab (s).

Table 12.4 Mass Flow Rate Field Gauge—CO_2 Mass Flow Rate.

Parameter	Value
Calibrated working flow rate range	Note 3
Initial mass flow rate accuracy	Note 3
Mass flow rate resolution	Note 3
Mass flow rate drift stability	Note 3

Note 3. These data to be negotiated with the mass flow meter vendor.

Table 12.5 Volume Flow Rate at each well pad

Parameter	Value
Calibrated working flow rate range	Note 3
Initial volume flow rate accuracy	Note 3
Volume flow rate resolution	Note 3
Volume flow rate drift stability	Note 3

Note 3. These data to be negotiated during the volume flow meter vendor selection and well engineering design

Table 12.6 Summary of Measurement Parameters for Field Gauges.

Parameters	Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Injection tubing temperature	Direct measurement	Note 4	Note 4	Note 4
Annulus pressure	Direct measurement	Note 4	Note 4	Note 4
Injection tubing pressure	Direct measurement	Note 4	Note 4	Note 4
Wellhead pressure	Direct measurement	Note 4	Note 4	Note 4
Downhole temperature	Direct measurement	Note 4	Note 4	Note 4
Injection mass flow rate	Direct measurement	Note 4	Note 4	Note 4

Note 4. These data to be negotiated during the volume flow meter vendor **selection** and well engineering design

Table 12.7 Actionable Testing and Monitoring Outputs

Activity or Parameter	Project Action Limit	Detection Limit	Anticipated Reading
External mechanical integrity via temperature anomaly	Thermal anomaly is the standard method of leakage detection; observe change in response between normal and shut-in operation	Note 5	Note 5
Internal mechanical integrity	Note 5	Note 5	Note 5
Surface pressure	Pressure approaching permitted limit	Note 5	Note 5

Activity or Parameter	Project Action Limit	Detection Limit	Anticipated Reading
Downhole pressure	Pressure approaching permitted limit	Note 5	Note 5
Groundwater or environmental parameters	Note 6	Note 6	Note 6
Above-confining-zone pressure Miocene	Note 6	Note 5	Note 5
Mismatch between modeled and observed IZ pressure response	Note 7	Note 5	Note 5
Mismatch between modeled and observed plume migration	Note 7	Note 5	Note 5

Note 5. These data to be negotiated during the well engineering design, after assessment of available instruments.

Note 6. The methodology for anomaly detection and attribution requires data collection over several years to identify natural and spatial variation and comparison to deep fluid compositions to identify a leakage signal. This will be added to the monitoring plan and used to follow up incident or allegation to attribute signal.

Note 7: Actual mismatch between modeled and observed IZ pressure response or plume tracking depends on recalibration of the model with new data, followed by a forward mode to determine if any unacceptable outcomes result from the new production of pressure and plume evolution.

12.2.4.2 A.4.b. Precision

Precision will be determined because of negotiation with selected vendors and contractors.

12.2.4.3 A.4.c. Bias

Laboratory assessment of analytical bias will be the responsibility of the individual laboratories per their standard operating procedures and analytical methodologies. For direct pressure or logging measurements, there is no bias.

12.2.4.4 A.4.d. Representativeness

For groundwater sampling, data representativeness expresses the degree to which data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. The sampling network has been designed to provide data representative of site conditions. For analytical results of individual groundwater samples representativeness will be estimated by ion and mass balances. Ion balances with ±10%

error or less will be considered valid. Mass balance assessment will be used in cases where the ion balance is greater than ±10% to help determine the source of error. For a sample and its duplicate, if the relative percent difference is greater than 10%, the sample may be considered non-representative.

12.2.4.5A.4.e. Completeness

For groundwater sampling, data completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions. It is anticipated that data completeness of 90% for groundwater sampling will be acceptable to meet monitoring goals. For direct pressure and temperature measurements, it is expected that data will be recorded no less than 90% of the time.

12.2.4.6A.4.f. Comparability

Data comparability expresses the confidence with which one data set can be compared to another. The data sets to be generated by this project will be very comparable to future data sets because of the use of standard methods and the level of QA/QC effort.

Direct pressure, temperature, and logging measurements will be directly comparable to previously obtained data.

12.2.4.7A.4.g. Method Sensitivity

To be discussed with the UIC Program Director post draft approval of the Testing and Monitoring Plan

Table 12.8 Pressure and Temperature—Downhole Gauge Specifications

Parameter	**Value**
Calibrated working pressure range	
Initial pressure accuracy	
Pressure resolution	
Pressure drift stability	
Calibrated working temperature range	
Initial temperature accuracy	
Temperature resolution	
Temperature drift stability	
Max temperature	
Instrument calibration frequency	

Table 12.9 Representative Logging Tool Specifications

Parameter	**[Insert Tool #1]**	**[Insert Tool #2]**	**[Insert Tool #3]**	**[Insert Tool #4]**
Logging speed				
Vertical resolution				
Investigation				
Temperature rating				
Pressure rating				

Table 12.10 Pressure Field Gauge.

Parameter	Value
Calibrated working pressure range	
Initial pressure accuracy	
Pressure resolution	
Pressure drift stability	

Table 12.11 Pressure Field Gauge—Injection Tubing Pressure

Parameter	Value
Calibrated working pressure range	
Initial pressure accuracy	
Pressure resolution	
Pressure drift stability	

Table 12.12 Pressure Field Gauge—Annulus Pressure.

Parameter	Value
Calibrated working pressure range	
Initial pressure accuracy	
Pressure resolution	
Pressure drift stability	

Table 12.13 Temperature Field Gauge—Injection Tubing Temperature.

Parameter	Value
Calibrated working temperature range	
Initial temperature accuracy	
Temperature resolution	
Temperature drift stability	

Table 12.14 Summary of Analytical Parameters for Corrosion Coupons

Parameters	Analytical Methods	Detection Limit/Range	Typical Precisions	QC Requirements
Mass				
[Insert Other parameter]				

Table 12.15 Summary of Analytical and Field Parameters for Fluid Samples in Frio and Miocene

Parameters	Analytical Methods(1)	Detection Limit/Range	Typical Precisions	QC Requirements
Cations: [List specific cations]				
Anions: [List specific anions]				
Dissolved CO_2				
Total dissolved solids				
Alkalinity				
pH				
Specific conductance				
Temperature (at bottom hole)				

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.

Table 12.16 Summary of Analytical and Field Parameters for Fluid Samples in Chicot aquifer

Parameters	Analytical Methods[(1)]	Detection Limit/Range	Typical Precisions	QC Requirements
Cations: [List specific cations]				
Anions: [List specific anions]				
Dissolved CO_2				
Total dissolved solids				
Alkalinity				
pH (field)				
Specific conductance (field)				
Temperature (field)				

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.

Table 12.17 Summary of Analytical and Field Parameters for Fluid Samples in soil gas

Parameters	Analytical Methods(1)	Detection Limit/Range	Typical Precisions	QC Requirements
Cations: [List specific cations]				
Anions: [List specific anions]				
Dissolved CO_2				
Total dissolved solids				
Alkalinity				
pH (field)				
Specific conductance (field)				
Temperature (field)				
[Insert Other parameter]				
[Insert Other parameter]				
[Insert Other parameter]				

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.

Table 12.18 Summary of Analytical and Field Parameters for Fluid Samples in Surface water

Parameters	Analytical Methods(1)	Detection Limit/Range	Typical Precisions	QC Requirements
Cations: [List specific cations]				
Anions: [List specific anions]				
Dissolved CO_2				
Total dissolved solids				
Alkalinity				
pH (field)				
Specific conductance (field)				
Temperature (field)				

Note 1: An equivalent method may be employed with the prior approval of the UIC Program Director.

12.2.5 A.5. Special Training/Certifications

12.2.5.1 A.5.a. Specialized Training and Certifications

The geophysical survey equipment and wireline logging tools will be operated by trained, qualified, and certified personnel, with documentation provided by the vendor. The subsequent data will be processed and analyzed according to industry standards environmental sampling will be conducted by qualified technicians who meet Louisiana requirements.

12.2.5.2 A.5.b/c. Training Provider and Responsibility

Training for personnel will be provided by the operator or by the subcontractor responsible for the data collection activity.

12.2.6 A.6. Documentation and Records

12.2.6.1 A.6.a. Report Format and Package Information

Reporting at the required frequency will contain all required project data, including testing and monitoring information as specified by the UIC Class VI permit. Data will be provided in electronic or other formats as required by the UIC Program Director.

12.2.6.2 A.6.b. Other Project Documents, Records, and Electronic Files

Other documents, records, and electronic files such as well logs, test results, or other data will be provided as required by the UIC Program Director.

12.2.6.3 A.6.c/d. Data Storage and Duration

GCS designated contractor will maintain the required project data as provided elsewhere in the permit.

12.2.6.4 A.6.e. QASP Distribution Responsibility

GCS will be responsible for ensuring that all those on the distribution list will receive the most current copy of the approved Quality Assurance and Surveillance Plan.

12.3 B. Data Generation and Acquisition

12.3.1 B.1. Sampling Process Design

12.3.1.1 B.1.a. Design Strategy

12.3.1.1.1 CO_2 Stream Monitoring Strategy

To be updated when dedicated streams of CO_2 have been identified and contracted for Project Minerva.

12.3.1.1.2 Corrosion Monitoring Strategy

To be updated when dedicated streams of CO_2 have been identified and contracted for Project Minerva.

12.3.1.1.3 Shallow Groundwater Monitoring Strategy

To be updated when dedicated streams of CO_2 have been identified and contracted for Project Minerva.

12.3.1.1.4 Deep Pressure Monitoring Strategy

To be updated when dedicated streams of CO_2 have been identified and contracted for Project Minerva.

12.3.1.2 B.1.b. Type and Number of Samples/Test Runs

To be updated when UIC Program Director has approved draft permit for Project Minerva.

12.3.1.3 B.1.c. Site/Sampling Locations

To be updated when UIC Program Director has approved draft permit for Project Minerva.

12.3.1.4 B.1.d. Sampling Site Contingency

To be updated when UIC Program Director has approved draft permit for Project Minerva.

12.3.1.5 B.1.e. Activity Schedule

To be updated when UIC Program Director has approved draft permit for Project Minerva.

12.3.1.6 B.1.f. Critical/Informational Data

To be updated when UIC Program Director has approved draft permit for Project Minerva.

B.1.g. Sources of Variability

To be updated when UIC Program Director has approved draft permit for Project Minerva.

12.3.2 B.2. Sampling Methods

12.3.2.1 B.2.a/b. Sampling SOPs

This element will be negotiated with selected geochemical labs

.Table 17, Stabilization Criteria of Water Quality Parameters During Shallow Well Purging.

This element will be negotiated with selected geochemical labs

Field Parameter	Stabilization Criteria
pH	
Temperature	
Specific conductance	
Dissolved oxygen	
Turbidity	

12.3.2.2 B.2.c. In-situ Monitoring

This element will be negotiated with selected geochemical labs

12.3.2.3 B.2.d. Continuous Monitoring

This element will be negotiated with selected geochemical labs

12.3.2.4 B.2.e. Sample Homogenization, Composition, Filtration

This element will be negotiated with selected geochemical labs

12.3.2.5 B.2.f. Sample Containers and Volumes

This element will be negotiated with selected geochemical labs

12.3.2.6 B.2.g. Sample Preservation

This element will be negotiated with selected geochemical labs

12.3.2.7 B.2.h. Cleaning/Decontamination of Sampling Equipment

This element will be negotiated with selected geochemical labs

12.3.2.8 B.2.i. Support Facilities

This element will be negotiated with selected geochemical labs

12.3.2.9 B.2.j. Corrective Action, Personnel, and Documentation

This is described in section D below

12.3.3 B.3. Sample Handling and Custody

12.3.3.1 B.3.a. Maximum Hold Time/Time Before Retrieval

This element will be negotiated with selected geochemical labs

12.3.3.2 B.3.b. Sample Transportation

This element will be negotiated with selected geochemical labs

12.3.3.3 B.3.c. Sampling Documentation

This element will be negotiated with selected geochemical labs

12.3.3.4 B.3.d. Sample Identification

This element will be negotiated with selected geochemical labs

Table 12.19 Summary of Sample Containers, Preservation Treatments, and Holding Times for CO_2 Gas Stream Analysis.

Sample	Volume/Container Material	Preservation Technique	Sample Holding time (ma
CO_2 gas stream			

Table 12.20 Summary of Anticipated Sample Containers, Preservation Treatments, and Holding Times for Ground Water Samples

Target Parameters	Volume/Container Material	Preservation Technique	Sample Holding Time
Cations: [List specific cations]			
Anions: [List specific anions]			
Dissolved CO_2			
Isotopes: [List specific isotopes]			
Alkalinity			
Field Confirmation: [List specific parameters]			

12.3.3.5 B.3.e. Sample Chain-of-Custody

This element will be supplied by the selected geochemical labs

12.3.4 B.4. Analytical Methods

12.3.4.1 B.4.a. Analytical SOPs

This element will be negotiated with selected geochemical labs

12.3.4.2 B.4.b. Equipment/Instrumentation Needed

This element will be negotiated with selected geochemical labs

12.3.4.3 B.4.c. Method Performance Criteria

This element will be negotiated with selected geochemical labs

12.3.4.4 B.4.d. Analytical Failure

This element will be negotiated with selected geochemical labs

12.3.4.5 B.4.e. Sample Disposal

This element will be negotiated with selected geochemical labs

12.3.4.6 B.4.f. Laboratory Turnaround

This element will be negotiated with selected geochemical labs

12.3.4.7 B.4.g. Method Validation for Nonstandard Methods

This element will be negotiated with selected geochemical labs

12.3.5 B.5. Quality Control

12.3.5.1 B.5.a. QC activities

12.3.5.1.1 Blanks

This element will be negotiated with selected geochemical labs

12.3.5.1.2 Duplicates

This element will be negotiated with selected geochemical labs

12.3.5.2 B.5.b. Exceeding Control Limits

This element will be negotiated with selected geochemical labs

12.3.5.3 B.5.c. Calculating Applicable QC Statistics

12.3.5.3.1 Charge Balance

This element will be negotiated with selected geochemical labs

12.3.5.3.2 Mass Balance

This element will be negotiated with selected geochemical labs

12.3.5.3.3 Outliers

GCS or designated vendor is responsible for assessment and documentation of outliers

12.3.6 B.6. Instrument/Equipment Testing, Inspection, and Maintenance

Element is deferred until design is advanced vendors selection

12.3.7 B.7. Instrument/Equipment Calibration and Frequency

12.3.7.1 B.7.a. Calibration and Frequency of Calibration

Element is deferred until design is advanced vendors selection

12.3.7.2 B.7.b. Calibration Methodology

Element is deferred until design is advanced vendors selection

12.3.7.3 B.7.c. Calibration Resolution and Documentation

Element is deferred until design is advanced vendors selection

12.3.8 B.8. Inspection/Acceptance for Supplies and Consumables

12.3.9 B.8.a/b. Supplies, Consumables, and Responsibilities

This design is deferred until the Testing and Monitoring Plan draft has been approved by the UIC Director.

12.3.10 B.9. Non-direct Measurements

12.3.10.1 B.9.a. Data Sources

Element is deferred until design is advanced vendors selection

12.3.10.2 B.9.b. Relevance to Project

Element is deferred until design is advanced vendors selection

12.3.10.3 B.9.c. Acceptance Criteria

Element is deferred until design is advanced vendors selection

12.3.10.4 B.9.d. Resources/Facilities Needed

Element is deferred until design is advanced vendors selection

12.3.10.5 B.9.e. Validity Limits and Operating Conditions

Element is deferred until design is advanced vendors selection

12.3.11 B.10. Data Management

12.3.11.1 B.10.a. Data Management Scheme

This design is deferred until the Testing and Monitoring Plan draft has been approved by the UIC Director.

12.3.11.2 B.10.b. Recordkeeping and Tracking Practices

This design is deferred until the Testing and Monitoring Plan draft has been approved by the UIC Director.

12.3.11.3 B.10.c. Data Handling Equipment/Procedures

This design is deferred until the Testing and Monitoring Plan draft has been approved by the UIC Director.

12.3.11.4 B.10.d. Responsibility

GCS or designated vendor is responsible for data management

12.3.11.5 B.10.e. Data Archival and Retrieval

This design is deferred until the Testing and Monitoring Plan draft has been approved by the UIC Director.

12.3.11.6 B.10.f. Hardware and Software Configurations

This design is deferred until the Testing and Monitoring Plan draft has been approved by the UIC Director.

12.3.11.7 B.10.g. Checklists and Forms

This design is deferred until the Testing and Monitoring Plan draft has been approved by the UIC Director.

12.4 C. Assessment and Oversight

12.4.1 C.1. Assessments and Response Actions

12.4.1.1 C.1.a. Activities to be Conducted

Assessments of each of the QASP elements:

I) CO_2 Stream Analysis Surface Sampling
II) Continuous recording of operational parameters
III) Corrosion monitoring
IV) Above Confining zone monitoring
IV) External Mechanical Integrity Testing (MIT)
V) Pressure fall-off testing
VI) Carbon Dioxide plume and Pressure from tracking
VII) Environmental monitoring at the Surface

12.4.1.2 C.1.b. Responsibility for Conducting Assessments

GCS or its designated subcontractor will assess data

12.4.1.3 C.1.c. Assessment Reporting

GCS will coordinate reporting of assessments

12.4.1.4 C.1.d. Corrective Action

GCS will coordinate corrective actions as warranted

12.4.2 C.2. Reports to Management

12.4.2.1 C.2.a/b. QA status Reports

This design is deferred until the Testing and Monitoring Plan draft has been approved by the UIC Director.

12.5 D. Data Validation and Usability

12.5.1 D.1. Data Review, Verification, and Validation

12.5.1.1 D.1.a. Criteria for Accepting, Rejecting, or Qualifying Data

Data will be evaluated to determine of the specified QC requirements have been met before data use.

12.5.2 D.2. Verification and Validation Methods

12.5.2.1 D.2.a. Data Verification and Validation Processes

Appropriate statistical software will be used to determine data consistency

12.5.2.2 D.2.b. Data Verification and Validation Responsibility

GCS or its designated subcontractor will verify and validate all data.

12.5.2.3 D.2.c. Issue Resolution Process and Responsibility

GCS or its designee will overview the data handling, management, and assessment process. Staff involved in these processes will consult with the GCS to determine actions required to resolve issues.

12.5.2.4 D.2.d. Checklist, Forms, and Calculations

Checklists and forms will be developed specifically to meet permit requirements. These will be detailed as site specific design advances.

12.5.3 D.3. Reconciliation with User Requirements

12.5.3.1 D.3.a. Evaluation of Data Uncertainty

Statistical software will be used to determine data consistency using methods consistent with UIC Program Director guidance.

12.5.3.2 D.3.b. Data Limitations Reporting

GCS will be responsible for ensuring that data developed by vendors is presented with the appropriate data-use limitations.

12.6 References

References will be provided as vendor information is gained.